4.7 External Radiation Surveillance

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External radiation is defined as radiation originating from a source outside the body. External radiation fields consist of a natural component and an artificial or manmade component. The natural component can be divided into 1) cosmic radiation, 2) primordial radionuclides in the earth's crust (primarily potassium-40, thorium-232, and uranium-238), and 3) an airborne component, primarily radon and its progeny. The manmade component consists of radionuclides generated for or from nuclear medicine, nuclear power, nuclear research, nuclear waste management, and consumer products. Environmental radiation fields may be influenced by the presence of radionuclides deposited as fallout from past atmospheric testing of nuclear weapons or those produced and released to the environment during the production or use of nuclear fuel. During any year, external radiation levels can vary from 15% to 25% at any location because of changes in soil moisture and snow cover (NCRP 1987).

The interaction of radiation with matter results in energy being deposited in matter. Ionizing radiation energy deposited in a mass of material is called radiation absorbed dose. A special unit of measurement called the rad was introduced for this concept in the early 1950s, and more recently, an International System (SI) unit called the gray (Gy) has been defined. For ease of comparison, one Gy is equivalent to 100 rad.

Thermoluminescence, or light output exhibited by thermoluminescent dosimeters, is proportional to the amount of radiation exposure (X), which is measured in units of roentgen (R). The exposure is multiplied by a factor of 0.98 to convert to a dose (D) in rad to soft tissue (USDHEW 1970). This conversion factor relating R to rad is, however, assumed to be unity (1) throughout this report for consistency with past reports. This dose is further modified by a quality factor, Q = 1 for beta and gamma radiation, and the product of all other modifying factors (N). N is assumed to be 1 to obtain dose equivalence (H), measured in rem. The Seivert, Sv, is the SI equivalent of the rem.

$$D \text{ (rad)} \approx X \text{ (R)} * 1.0$$

$$H \text{ (rem)} \approx D * N * Q$$

To convert to SI units of Gy and Sv, divide rad and rem by 100, respectively.

External radiation exposure rates were measured at locations on and off the Hanford Site using thermoluminescent dosimeters. External radiation and contamination surveys were also performed with portable radiation survey instruments at locations on and around the Hanford Site. This section describes how external radiation was measured, how surveys were performed, and the results of these measurements and surveys.

External Radiation Measurements

In January 1995, a new Harshaw 8800 series system replaced the old Hanford standard environmental dosimeter system. The Harshaw dosimeter consists of two TLD-700 and two TLD-200 chips. This dosimeter provides both shallow- and deep-dose measurement capabilities. Thermoluminescent dosimeters are positioned one meter (3.3 ft) above the ground at various locations onsite (Figure 4.7.1), around the Site perimeter, in nearby and distant communities, (Figure 4.7.2), and along the Hanford Reach of the Columbia River (Figure 4.7.3). The thermoluminescent dosimeters are collected and read quarterly. The two TLD-700 chips at each location are used to determine the average total environmental dose at that location. The average dose rate is computed by dividing the average total environmental dose by the length of time the thermoluminescent dosimeter was in the field. The two TLD-200 chips are included to determine doses in the event of a radiological emergency.

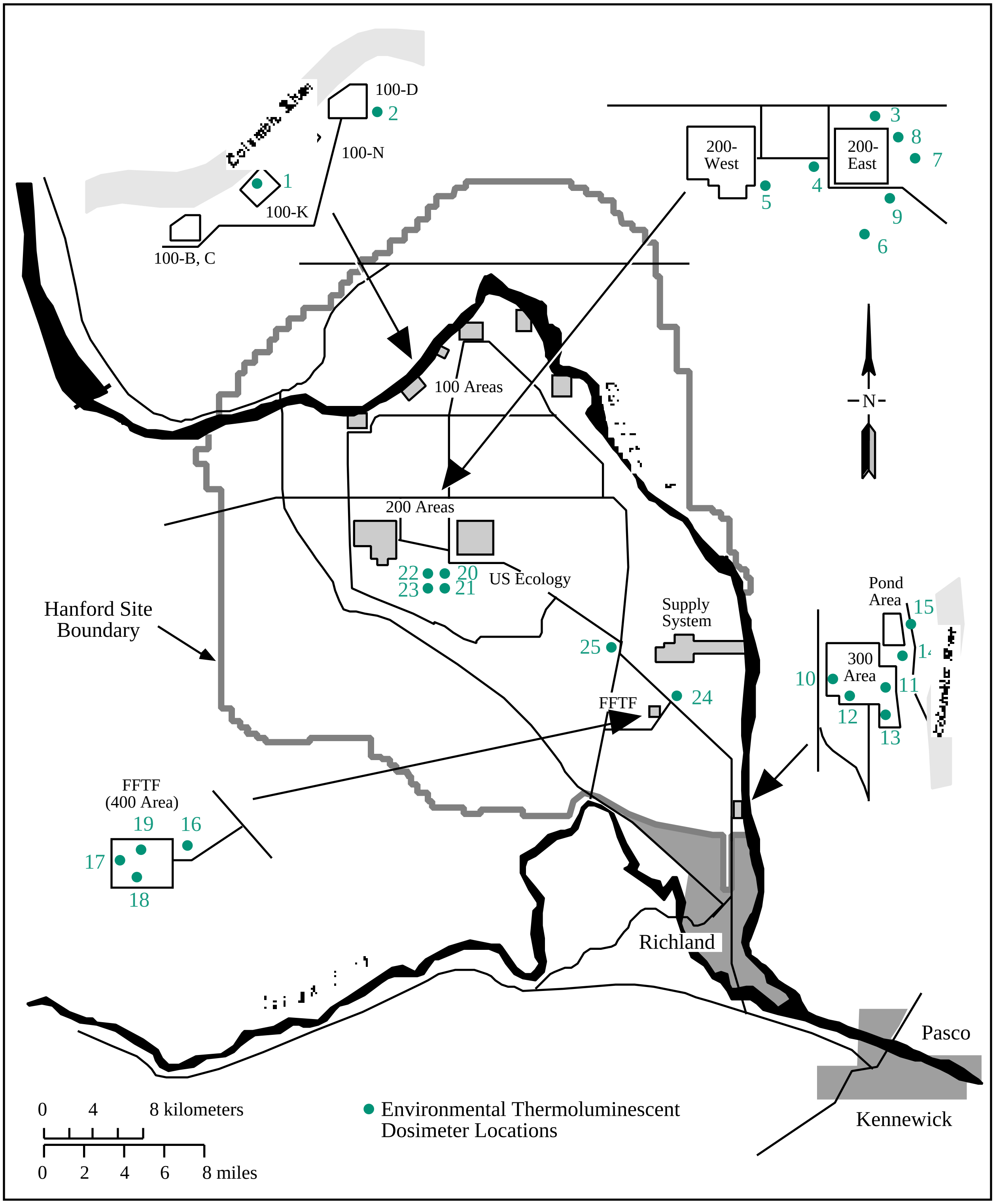

Figure 4.7.1. Thermoluminescent Dosimeter Locations and Station Numbers on the Hanford Site, 1995

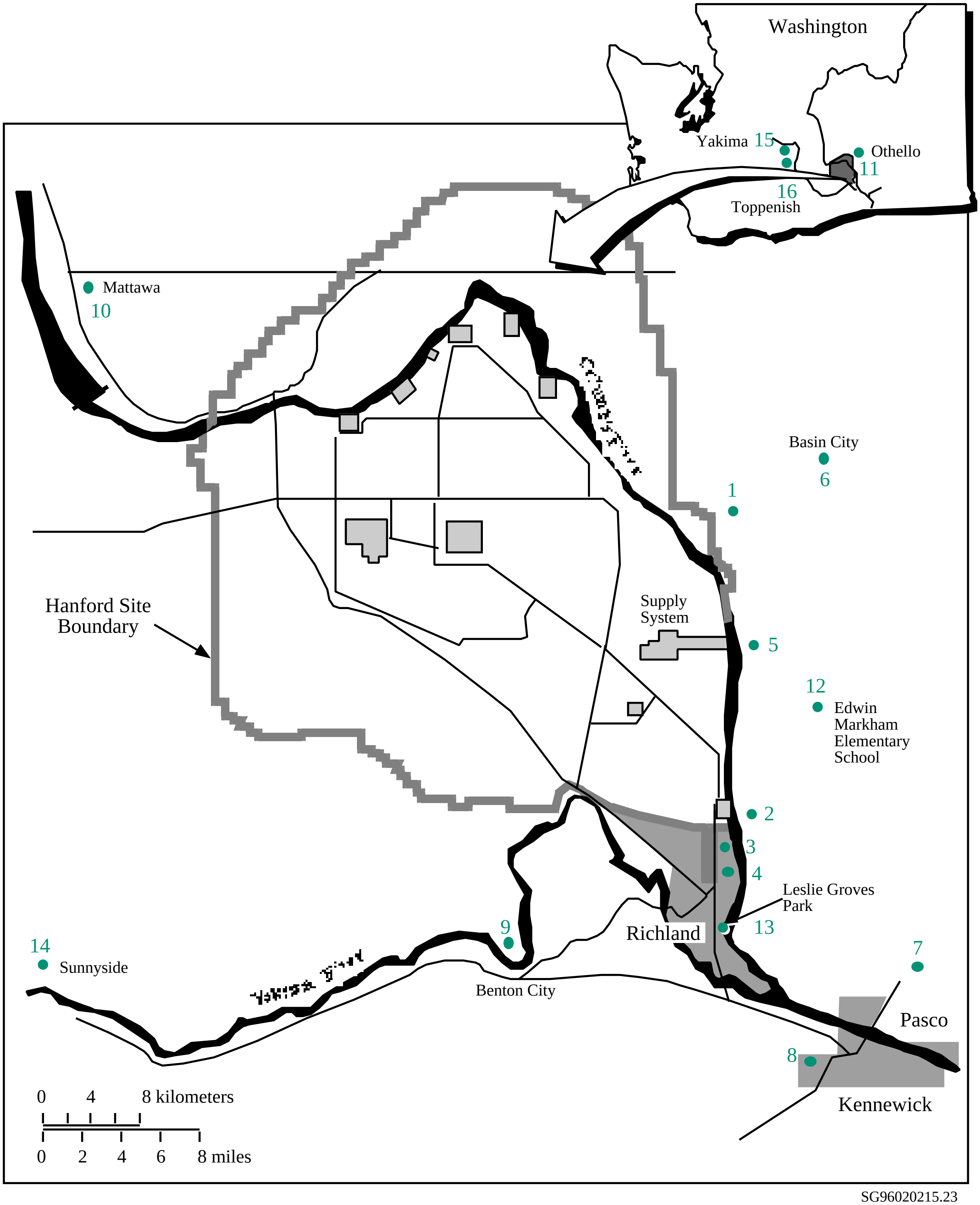

Figure 4.7.2. Thermoluminescent Dosimeter Locations and Station Numbers for Community, Distant, and Perimeter Sites, 1995

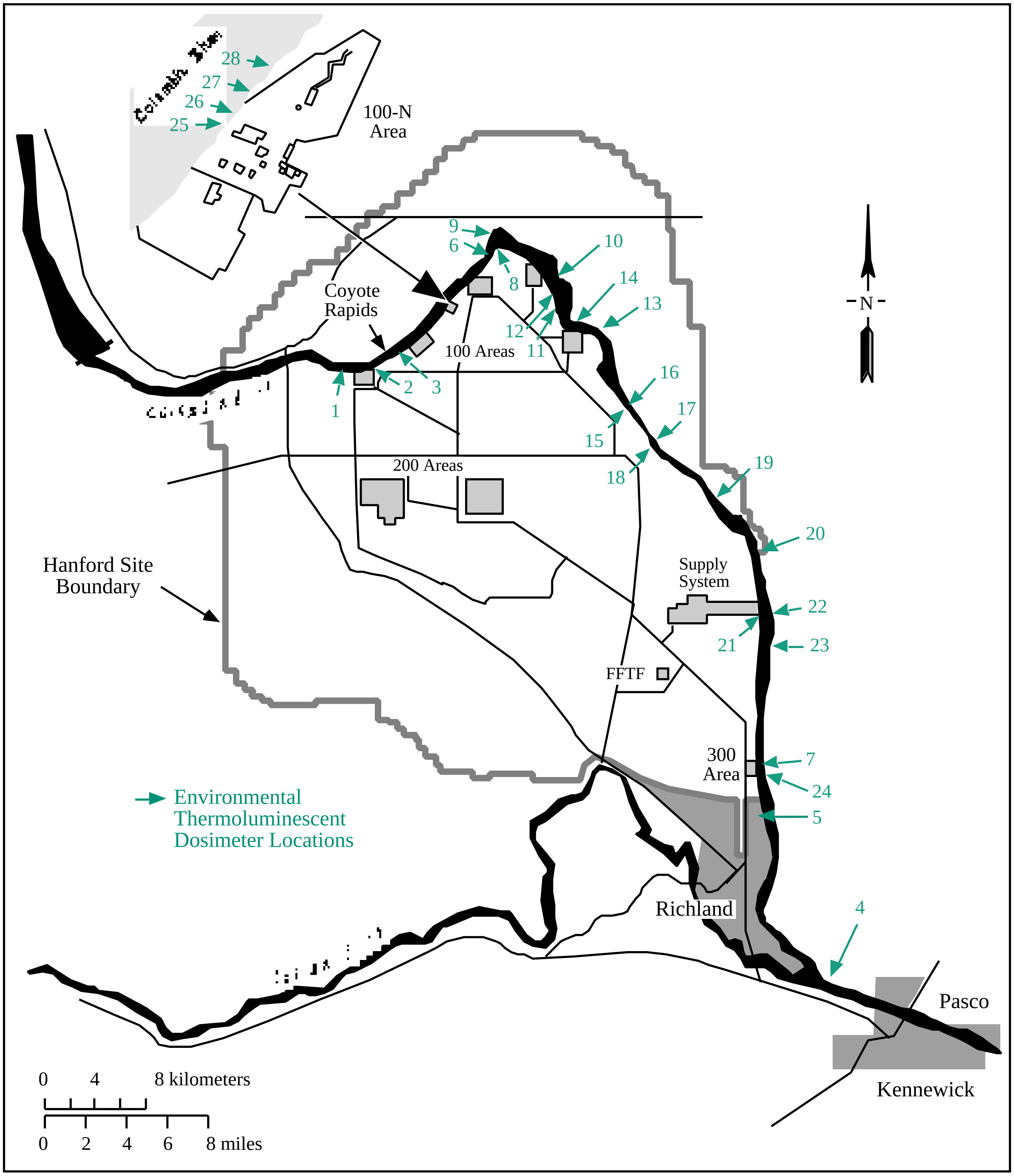

Figure 4.7.3. Thermoluminescent Dosimeter Locations and Station Numbers on the Hanford Reach of the Columbia River, 1995

All community, and most of the onsite and perimeter locations, are collocated with air monitoring stations, including the eight community-operated environmental surveillance stations identified in Section 4.1, "Air Surveillance." These locations were selected based on historical determinations of the highest potentials for public exposures (access areas, downwind population centers) from past and current Hanford operations.

Twenty-eight thermoluminescent dosimeter locations have been established on the Columbia River shoreline, from upstream of the 100-B Area to just downstream of Bateman Island at the mouth of the Yakima River. The public has access to most of this shoreline. Historically, dose rates measured along the shoreline have been higher than typical background rates. Sula (1980) attributed these elevated rates to cobalt-60 and europium-154 deposited in shoreline sediments as a result of liquid releases to the Columbia River during past reactor operations in the 100 Areas.

External Radiation Results

Perimeter and offsite locations, primarily downwind of the Site and near population centers, were monitored with thermoluminescent dosimeters. Thermoluminescent dosimeter exposures have been converted to dose equivalent rates by the process described above. Table 4.7.1 shows maximum and average dose rates for perimeter and offsite locations measured in 1995 and the previous 5 years. Quarterly dose equivalent rates (mrem/day) at each location were converted to annual dose equivalent rates (mrem/yr) by averaging the quarterly dose rates and multiplying by 365 days/yr. External dose rates reported in Tables 4.7.1 through 4.7.3 include the maximum annual average dose rate (±2 standard error of the mean) for all locations within a given area, and the mean dose rate (±2 standard error of the mean) for each area. The mean dose rates were computed by averaging annual means for each location within an area.

In 1995, the average perimeter external radiation dose rate was 86 ± 8 mrem/yr, while in 1994, the average was 110 ± 9.2 mrem/yr (Table 4.7.1). This 23% reduction in the exposure rate for the year may be attributed to the new Harshaw environmental dosimeter used in 1995. The new dosimeters are packaged in a holder that has an O-ring seal and is more opaque than the previous system. The newer packaging provides protection from light, moisture, and dirt and may improve the low-dose performance of the new system. Variations in natural background radiation can also occur as a result of changes in annual cosmic radiation (up to 10%) and terrestrial radiation (15 to 25%, [NCRP 1987]). Other factors possibly affecting the annual dose rates reported here may include variations in the sensitivity of individual thermoluminescent dosimeter zero-dose readings, fading, random errors in the readout equipment, procedural errors (Rathbun 1989), and changes in thermoluminescent dosimeter station locations.

Table 4.7.1. Average and Maximum External Dose Rates Measured by Thermoluminescent Dosimeters at Perimeter and Offsite Locations, 1995 Compared to Values from the Previous 5 Years

		Dose Rate, mrem/yr[(a)]				
		1995		1990-1994		
Sampling Area	Map Locations[(b)]	Maximum[(c)]	Mean[(d)]	No. of Samples	Maximum[(c)]	Mean[(d)]
Perimeter	1 - 5	93 ± 2	86 ± 8	40	120 ± 17	94 ± 4
Nearby communities	6 - 13	88 ± 4	76 ± 4	41	106 ± 16	88 ± 3
Distant communities	14 - 16	78 ± 2	72 ± 8	16	100 ± 11	86 ± 4

(a) Quarterly integrated readings in mR/d were converted to annual dose equivalent rates (mrem/yr).
(b) All locations are shown in Figure 4.7.2.
(c) Maximum annual average dose rate (±2 standard error of the mean) for all locations within a given area.
(d) Means ±2 standard error of the mean computed by averaging annual means for each location within the area.

Table 4.7.2. Average and Maximum External Dose Rates Measured Along the Hanford Reach of the Columbia River, 1995 Compared to Values from the Previous 5 Years

		Dose Rate, mrem/yr[a]				
		1995		1990-1994		
Sampling Area	Map Locations[b]	Maximum[c]	Mean[d]	No. of Samples	Maximum[c]	Mean[d]
Typical shoreline	1 - 24	114 ± 4	90 ± 3	116	167 ± 5	104 ± 4
100-N Shoreline[e]	25 - 28	187 ± 7	175 ± 12	20	356 ± 143	225 ± 27
All shoreline		187 ± 7	103 ± 12	136	356 ± 143	122 ± 3

(a) Quarterly integrated readings in mR/d were converted to annual dose equivalent rates (mrem/yr).
(b) All locations are shown in Figure 4.7.3.
(c) Maximum annual average dose rate (±2 standard error of the mean) for all locations within a given area.
(d) Means ±2 standard error of the mean computed by averaging annual means for each location within the area.
(e) Monthly integrated exposure readings in mR/d converted to annual dose equivalent rates in mrem/yr.

Table 4.7.3. Average and Maximum External Dose Rates for Thermoluminescent Dosimeter Locations on the Hanford Site, 1995 Compared to Values from the Previous 5 Years

		Dose Rate, mrem/yr[a]				
		1995		1990-1994		
Sampling Area	Map Locations[b]	Maximum[c]	Mean[d]	No. of Samples	Maximum[c]	Mean[d]
100 Areas	1 - 2	86 ± 2	79 ± 14	15	120 ± 35	94 ± 6
200 Areas	3 - 9	93 ± 3	88 ± 3	42	121 ± 10	97 ± 3
300 Areas	10 - 15	88 ± 4	84 ± 3	30	110 ± 18	94 ± 3
400 Areas	16 - 19	87 ± 3	84 ± 3	22	111 ± 18	94 ± 4
600 Areas	20 - 25	135 ± 9	102 ± 16	31	183 ± 16	110 ± 10
Combined Onsite		135 ± 9	86 ± 4	140	183 ± 16	98 ± 3

(a) Quarterly integrated readings in mrem were converted to annual dose equivalent rates.
(b) Locations are identified in Figure 4.7.1.
(c) Maximum annual average dose rate (±2 standard error of the mean) for all locations within a given area.
(d) Means ±2 standard error of the mean computed using pooled quarterly data.

The average background external radiation dose rate (in distant communities) in 1995 was 72 ± 8 mrem/yr as compared to the perimeter average of 86 ± 8 mrem/yr. This 15% difference in exposure rate may be partially due to natural geographic variations in terrestrial radiation (the soils at many of the perimeter locations are rich in potassium-40 and thorium isotopes [Rathbun 1989]), to variations resulting from human activity, or to use of the new dosimetry system for the reasons stated above. Human activities affecting the average dose rates may include landscape modifications such as buildings and other construction, which may shield a portion of the terrestrial component. Figure 4.7.4 graphically displays a comparison between, and trends of, onsite, perimeter,

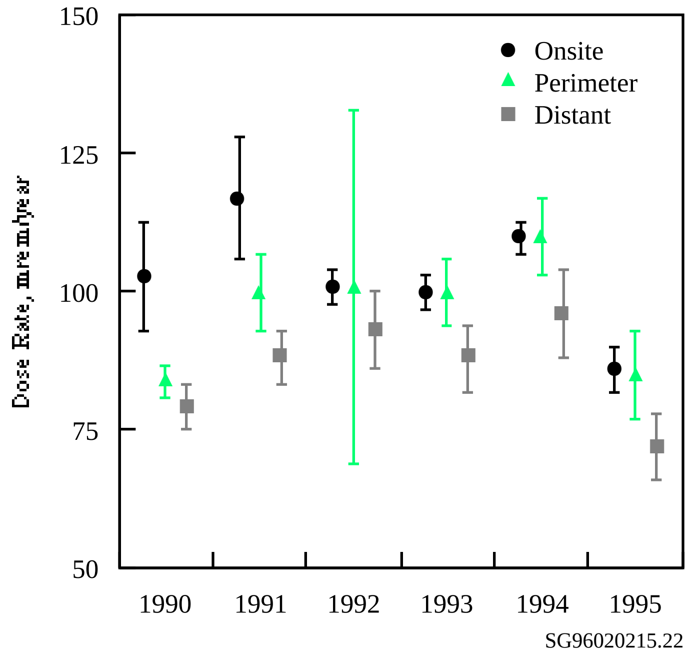

Figure 4.7.4. Annual Average Dose Rates (±2 standard error of the mean), 1990 Through 1995

and distant thermoluminescent dosimeter locations during 1990 through 1995. Year-to-year variability is possible for the reasons outlined above, and 10% annual variability is possible (NCRP 1987).

Figure 4.7.3 shows locations of thermoluminescent dosimeters positioned along the Columbia River shoreline, and Table 4.7.2 shows the maximum and average measured dose rates for shoreline locations. Dose rates were highest near the 100-N Area shoreline and two to three times higher than typical shoreline dose rates. The high rates measured in the 100-N Area historically have been attributed to past waste management practices in that area. In 1995, however, third quarter thermoluminescent dosimeter readings showed a marked increase in the 100-N shoreline exposures. The increase was due to work that took place in August. This work involved removing reactor core fuel spacers from a storage vault (silo), transferring them to rail cars, and shipping them to another location. These spacers were radioactively “hot” and were the cause of elevated thermoluminescent dosimeter readings at shoreline sites near the 105-N building. The maximum quarterly reading from the 100-N Area shoreline was 405 mrem/yr for the third quarter thermoluminescent dosimeter at the station below the 100-N stack. The public does not have legal access to the 100-N Area shoreline, but does have access to the adjacent Columbia River. The dose implications associated with this access are discussed in Section 5.0, “Potential Radiation Doses from 1995 Hanford Operations.”

Table 4.7.3 summarizes the results of 1995 measurements, which are grouped by operational area. The average dose rates in all operational areas were higher than average dose rates measured at background locations. The highest average dose rate onsite was seen in the 600 Area and was due to waste disposal activities at US Ecology Inc., a non-DOE facility.

Radiation Survey Results

In 1995, hand-held survey instruments were used to perform radiation surveys at selected Columbia River shoreline thermoluminescent dosimeter locations. These surveys provided a coarse screening for elevated radiation fields. The surveys showed that radiation levels were comparable to levels observed at the same locations in previous years. The highest levels were seen along the Columbia River shoreline in the 100-N Area and ranged from 3 to 20 µrem/h. Survey information is not included in the 1995 data volume (Bisping 1996), but is maintained in the Surface Environmental Surveillance Project files at Pacific Northwest National Laboratory and can be obtained by written request.

Gamma Radiation Measurements

During 1995, gamma radiation levels in air were continuously monitored at three community-operated air monitoring stations. These stations were located in Leslie Groves Park in Richland, at Edwin Markham Elementary School in north Franklin County, and at Basin City Elementary School (see Figure 4.1.1). Measurements were collected to determine ambient gamma radiation levels near and downwind of the Hanford Site, to display real-time exposure rate information to the public living near the station, and to be an educational aid for the teachers who manage the stations (see Section 6.4, "Community-Operated Environmental Surveillance Program").

Measurements at Basin City and Edwin Markham schools were obtained using Reuter-Stokes Model S-1001-EM19 pressurized ion chambers connected to Reuter-Stokes RSS-112 Radiation Monitoring Stations. Data were collected every 5 seconds, and an average reading was recorded on an electronic data card every 30 minutes. Data cards were exchanged monthly. Readings at Leslie Groves Park were collected every 10 seconds with a Reuter-Stokes Model RSS-121 pressurized ion chamber, and an average reading was recorded every hour by a flat panel computer system manufactured by Computer Dynamics. Data were obtained from the computer monthly via modem. Data were not collected at every station every month because of problems with instrument batteries and equipment failures that were caused by high ambient air temperatures. The computer at Leslie Groves Park was inoperable for several months when the hard drive failed and had to be replaced.

Table 4.7.4. Average Exposure Rates Measured with Pressurized Ion Chambers at Three Offsite Locations

Sampling Locations[c]	Average Exposure Rate (μR/h)[a](number of readings)[b]		
Month	Leslie Groves Park[d]	Basin City[e]	Edwin Markham[e]
January	8.9 ± 0.7 (743)	ND[f]	8.9 ± 0.6 (1,493)
February	8.6 ± 0.6 (473)	8.3 ± 0.5 (1,342)	ND
March	ND	8.4 ± 0.4 (1,555)	8.7 ± 0.5 (1,358)
April	8.6 ± 0.3 (261)	8.4 ± 0.4 (1,356)	ND
May	8.5 ± 0.3 (162)	ND	ND
June	ND	8.3 ± 1.3 (819)	ND
July	ND	ND	8.5 ± 0.3 (1,443)
August	ND	ND	ND
September	ND	8.3 ± 0.5 (1,081)	8.6 ± 0.4 (1,662)
October	8.7 ± 0.5 (290)	8.3 ± 0.5 (982)	8.7 ± 0.4 (1,263)
November	8.6 ± 0.6 (721)	8.4 ± 0.4 (1,445)	8.8 ± 0.4 (1,444)
December	8.7 ± 0.6 (745)	8.4 ± 0.5 (1,480)	8.8 ± 0.5 (1,567)

(a) Averages are ±2 times the standard error of the mean.
(b) Number of 30- or 60-minute averages used to compute monthly average.
(c) Sampling locations are illustrated in Figure 4.1.1.
(d) Readings are stored every 60 minutes. Each 60-minute reading is an average of 360 individual measurements.
(e) Readings are stored every 30 minutes. Each 30-minute reading is an average of 360 individual measurements.
(f) Equipment problems, no data collected.

The measurements recorded at all three locations during the year were similar and unremarkable. Thirty- and 60-minute averages ranged from 11.7 microroentgen per hour (µR/h) at Edwin Markham School for January and September to 7.2 µR/h in Leslie Groves Park in November. Average monthly readings at all stations were consistently between 8.3 and 8.9 µR/h (Table 4.7.4). These dose rates are consistent with the dose rates measured by the thermoluminescent dosimeters located at these stations and are comparable to the dose rates measured with thermoluminescent dosimeters at distant (background) stations.